Concrete Overlays – Sustainable Pavement Preservation Techniques Helping DOT's Adjusting to New Realities of Shrinking Resources

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Abstract

It is important for transportation agencies to have a variety of pavement maintenance, rehabilitation and reconstruction techniques to deal with the ever deteriorating roadway infrastructure. Concrete overlays are one option to providing a sustainable solution for resurfacing and rehabilitating existing pavements.

This paper explains the various types of bonded and unbonded concrete overlays available to transportation agencies when analyzing pavement preservation options for their deteriorated sections of roadway. It also looks at the steps in evaluating existing pavement condition, as well as, identifying the appropriate overlay system to use for the pavement being evaluated. A discussion on design, construction and other general details of overlays is also provided. In additional the many sustainable attributes of concrete overlays such as utilizing the existing pavement structure as pavement base, truck fuel savings, light reflective surface, decreased energy use and use of industrial by-products will also be discussed.

The paper will also identify four concrete overlay projects (two bonded overlays and two unbonded overlays) constructed in Canada and provide design details. Comments will also be provided on the performance of these projects.

1.0 Introduction

Concrete overlays have been successfully used in Canada and United States for several decades on roadways and intersections. The procedure has extended pavement life for as long as 30 years. Concrete overlays, formerly known as whitetopping, inlays and ultra-thin whitetopping, are just what their name suggests - the overlaying of concrete on asphalt, composite or existing concrete pavements for environmentally friendly, long lasting and cost effective rehabilitation. Busy intersections and asphalt roads rutted by heavy truck and bus traffic can be rejuvenated with a rigid surface that won't rut or shove. Depending on the application, traffic requirements and condition of the asphalt structure an overlay may be as thin as 50 mm or as thick as 200 mm or more.

Concrete overlays may be either *bonded* or *unbonded*. *In general, bonded* overlays are normally used for resurfacing and minor rehabilitation while unbounded overlays are used to rehabilitate pavement with some structural deterioration. Figure 1 below depicts the various bonded and unbonded concrete overlay systems. Figure 2 below shows when the various types of bonded and unbonded overlays are typically used for maintenance, rehabilitation and reconstruction needs.

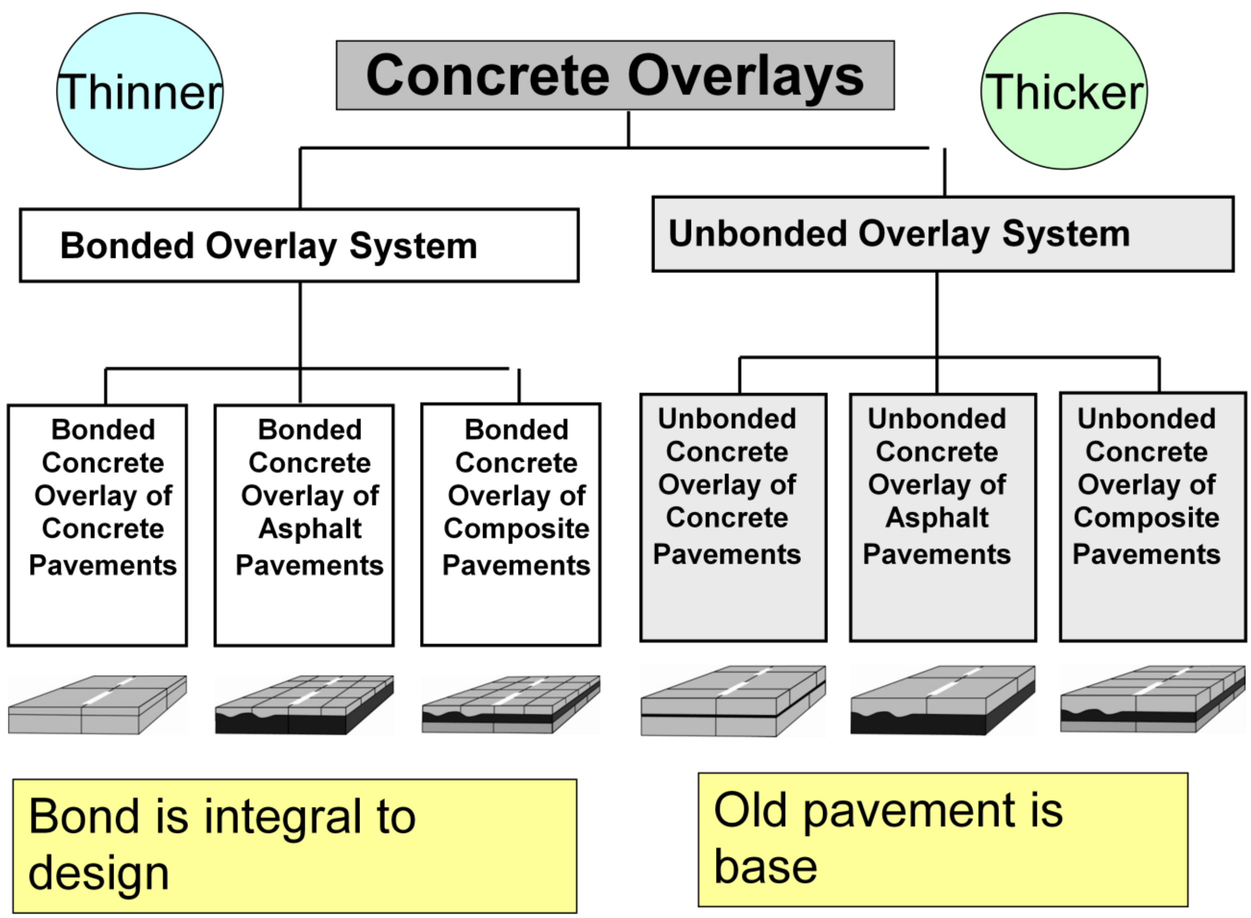

Figure 1: Various Bonded and Unbonded Concrete Overlay Systems
Source: National Concrete Pavement Technology Center [Harrington 2008]

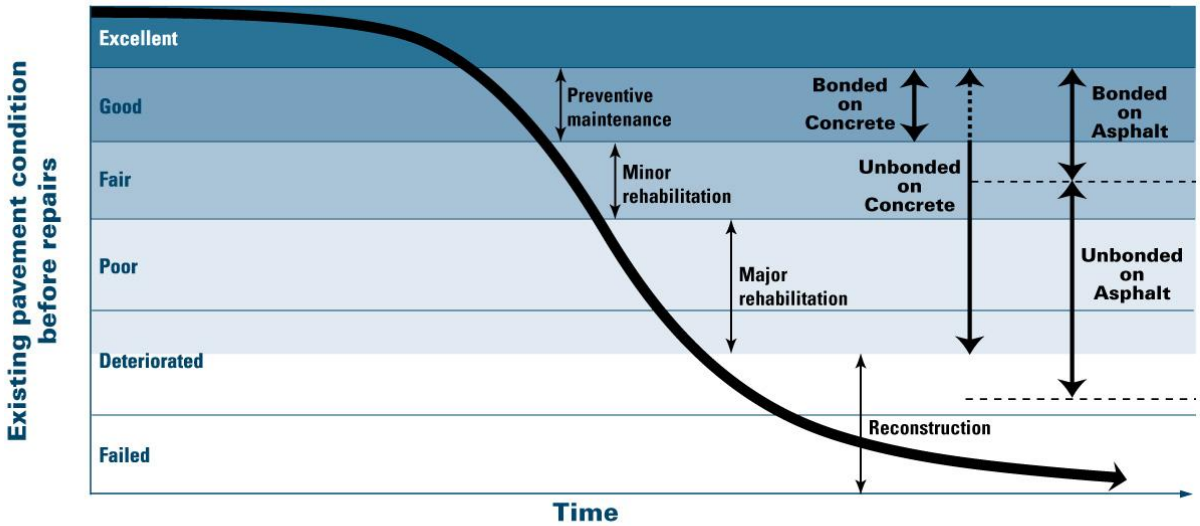

Figure 2: Typical Bonded and Unbonded Concrete Solutions for Maintenance, Rehabilitation and Reconstruction Needs
Source: National Concrete Pavement Technology Center [Harrington 2008]

2.0 Uses and Key Issues for Concrete Overlay Types

The most comprehensive document on concrete overlays is a product of the National Concrete Pavement Technology Center (CP Tech Center). The document entitled, “Guide to Concrete Overlays – Sustainable Solutions for Resurfacing and Rehabilitating Existing Pavements” provides a detailed look at the various bonded and unbonded overlay systems, identifies the key areas to evaluate in the existing pavement, provides an approach for selecting the appropriate concrete overlay solution, discusses design and construction of the overlays and looks at the repairs of overlays. The document identifies the following for each of the three bonded overlay options and three unbonded overlay options noted in Figure 1:

1) Existing pavement condition when the overlay should be used
2) Applications for the specific overlays
3) Keys to success for using the various overlay systems

Bonded overlays provide added structural capacity and / or eliminate surface distresses such as rutting and shoving. When utilizing bonded overlays the existing pavement (concrete or asphalt) must be in good condition with no significant stresses, as it becomes an integral part of the pavement structure. For bonded asphalt overlays ruts of 50 mm or more will need to be milled to correct the asphalt profile. Milling the asphalt surface also helps improve the bond between the concrete overlay and asphalt interface. It is important to have a minimum of 75 to 100 mm of structurally sound asphalt remaining after milling to ensure proper performance of the bonded overlay. Bonded overlays are generally thin - 50 to 125 mm range. The bond between the two pavements is critical for the performance of the new pavement structure. It ensures the concrete overlay and existing asphalt pavement performs as one structure with the asphalt continuing to carry a significant portion of the load.

Unbounded overlays are basically new pavements constructed on an existing pavement which acts as a stable base of known performance. The term unbounded means the bond between the pavements is not required to achieve the desired performance of the new pavement structure. These pavements are normally thicker than bonded overlays, usually in the range of 100 to 275 mm. Preoverlay repairs are generally not required unless there are significant distress areas that are shifting and moving or the subgarde / subbase is not stable. Milling of the existing asphalt surface may be required if the surface distortions, such as rutting or shoving, are 50 mm or more. If required, a layer of asphalt can be placed between the existing and new pavement to prevent any stresses in the old pavement from affecting the performance of the new one.

For thick overlays, it may be necessary to mill down the original road surface 100 to 150 metres approaching / exiting an overpass to ensure proper clearance for truck traffic.

3.0 Evaluating Existing Pavement Condition

Evaluating the existing pavement condition is an important part of the pavement preservation and rehabilitation process. Performing a comprehensive evaluation of the existing pavement provides valuable information regarding its performance, capabilities and limitations. Some of the key information which can be obtained is as follows:

1) Presence, type, and extent of distress
2) Structural condition and load-carrying capacity
3) Functional characteristics of the pavement such as roughness, friction, and noise
4) Characteristics and behaviour of in-place pavement materials [Harrington 2008]

The activities performed as part of the pavement evaluation process will depend on the available information and can vary from project to project. The general process can be divided into the following steps:

1) Historical data collection, records review, and future projections
2) Visual surface examination
3) Core analysis
4) Possible additional tests, including analyses of material-related distresses, drainage, roughness and surface friction, and grade restrictions
5) Condition assessment profile, summarized in condition assessment evaluation report [Harrington 2008]

Guide to Concrete Overlays – Sustainable Solutions for Resurfacing and Rehabilitating Existing Pavements identifies a five step initial evaluation process to help develop a pavement evaluation report and pavement condition ranking. The five steps are as follows:

1) Pavement History and Performance Goals including items such as:
    a. Pavement material, design, age, thickness and layers
    b. Existing traffic and performance level
    c. Design life
    d. Remaining life
    e. Desired traffic and performance level
    f. Desired design life
    g. Evaluation and grade restrictions
    h. Other historical information

2) Visual examination
    a. Pavement is rated as in either good, fair, poor, or deteriorated

3) Core Analysis
    a. Type of distress
    b. Depth of distress
    c. Verification of thickness for pavement base / subbase

4) Optional Analysis
    a. Material-related tests
    b. Subsurface tests
    c. Surface texture tests

5) Condition Assessment Profile
    a. Concrete surface deficiencies
    b. Concrete structural deficiencies
    c. Asphalt surface deficiencies
    d. Asphalt structural deficiencies [Harrington 2008]

Upon completion of the above analysis the information is then used to assist the agency in choosing on the most appropriate concrete overlay system.

4.0 Selecting Appropriate Concrete Overlay Solution

Guide to Concrete Overlays – Sustainable Solutions for Resurfacing and Rehabilitating Existing Pavements provides a decision tree flowchart to help an agency choose the most appropriate concrete pavement overlay system. Figures 3 below shows the first portion of the overlays document flowchart which identifies the condition of the existing concrete or asphalt pavement as:

1) Good or better
2) Fair or better
3) Poor or better
4) Deteriorated or better

Figure 4 shows the decision boxes which help the user decide which type of overlay system is best for the condition of the existing pavement they are evaluating. The decision tree flowchart can be found on pages 10 and 11 of the CP Tech Center overlay document.

The overlay document also provides a two page summary on each concrete overlay solution noting the following information:

1) Uses of the overlay solution
2) Key overlay design issues including overlay thickness, mixture design, drainage repair
3) Preoverlay work including preoverlay repairs, milling, surface preparation, surface cleaning
4) Construction work including concrete pavement placement, curing, joint sawing and future repairs

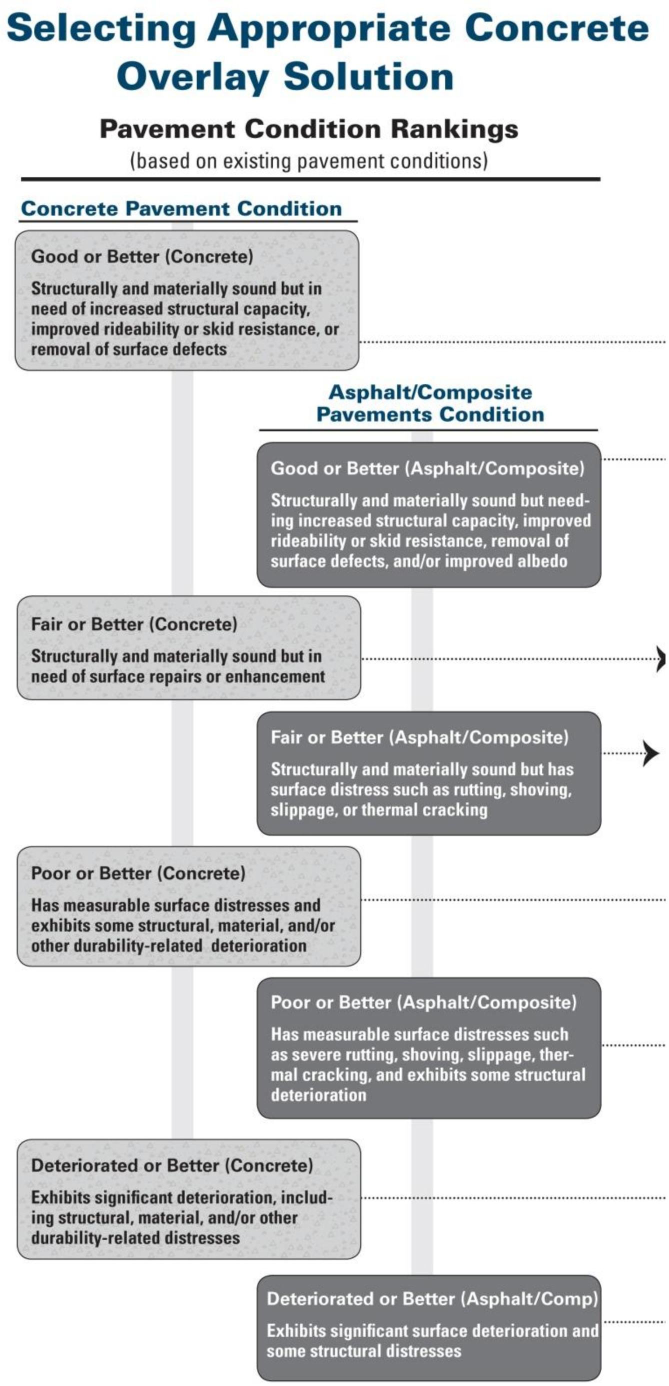

Figure 3: Pavement Condition Ranking Portion of Flowchart for Choosing the Appropriate Concrete Overlay
Source: National Concrete Pavement Technology Center [Harrington 2008]

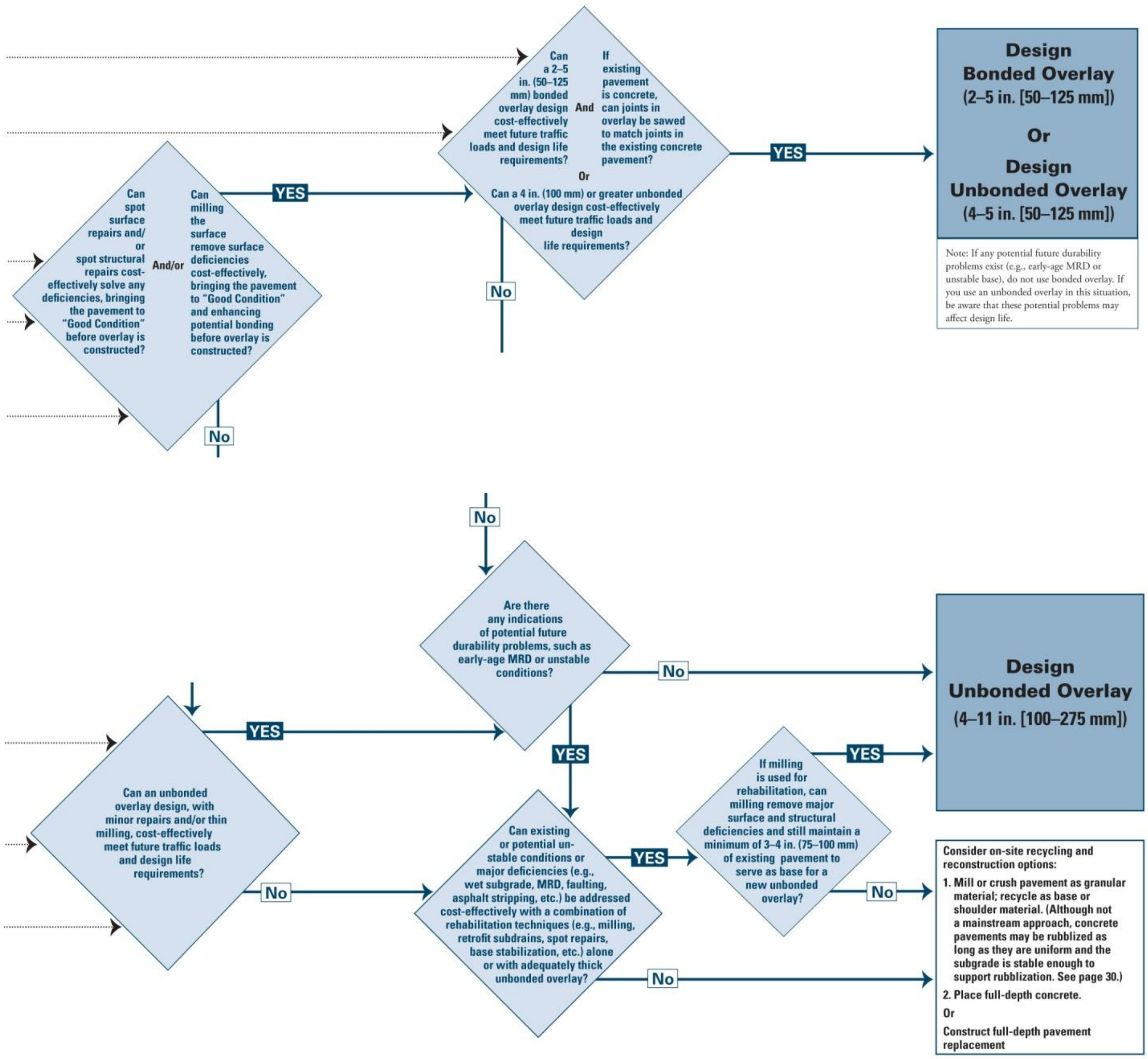

Figure 4: Decision Boxes Portion of Flowchart for Choosing the Appropriate Concrete Overlay
Source: National Concrete Pavement Technology Center [Harrington 2008]

5.0 Design, Construction and Other Details

Utilizing sustainable concrete overlays helps government agencies rehabilitate their aging roadway networks in a cost effective manner. The CP Tech Center overlay document provides clear, reliable guidance for designing high-quality concrete overlays and an outline of strategies and resources necessary to implement concrete overlay projects as part of an overall pavement maintenance and rehabilitation program. The information in the design section of the overlay document has been collected from several valuable resources published by ACI, AASHTO, FHWA, World Road Association (PIARC), NCHRP, ACPA, PCA, the U.S. Army Corps of Engineers, Federal Aviation Administration, and various state departments of transportation. Existing procedures are based on a variety of underlying assumptions and design strategies. It is important for concrete overlay designers to understand the interaction of design with both the selection of mixture design and the construction process. It is important to note possibly the most critical design principle is that the concrete overlay and the underlying pavement should be viewed as a system. [Harrington 2008]

The CP Tech Center overlay document has a great table entitled, "Summary of Design Considerations for Different Types of Concrete Overlay Systems", which identifies the various design methods used for each type of bonded and unbonded overlay system. The table also notes: the design failure mode; deficiencies/shortcomings/or items to note; if fiber model was included in design procedure; if joint spacing is a design consideration; and k-value location.

Key points for concrete overlay construction are also identified in CP Tech Center concrete overlays document. A table entitled "Concrete Paving Construction Practices for Overlays" provides details points on seven key construction considerations for bonded and unbonded applications including the following:

1) Mix design
2) Grade control
3) Preoverlay repairs for uniform support
4) Surface preparation
5) Concrete placement
6) Curing to prevent rapid loss of water from the concrete
7) Joints

The document also provides a very detailed chapter on accelerated construction practices identifying the many factors to consider in the mix design, concrete transportation, traffic considerations, construction staging, construction, and opening pavement considerations.

Other information of note in the overlay document is as follows:

1) Curb and gutter design titles
2) Manhole details
3) Transition details for bonded and unbonded overlays
4) Widening unit for bonded / unbonded concrete overlays
5) Lane addition details
6) Concrete materials
7) Managing concrete overlay work zones under traffic
8) Considerations for Developing Project and Supplemental Specifications
9) Repairs for concrete overlays

6.0 Benefits of Concrete Overlays

As demonstrated in the proceeding sections concrete overlays can be used to rehabilitate all types of pavement in a variety of conditions to a desired service life. Concrete pavements have long been known as a long lasting and low maintenance pavement. Figure 5 identifies many of concrete's additional sustainable benefits beyond longevity. Several papers have been written on the sustainability of concrete pavement including two TAC papers entitled:

1) Helping Build A Sustainable Future by Constructing Roadways with Portland Cement Concrete Pavement in 2006

2) Cement and Concrete Industries Contribution to Climate Change Mitigation in 2009

These papers detail some of the many sustainable benefits of concrete pavement including a variety of the points identified in the following sections on economic and environmental benefits. Additional information on the sustainability of concrete pavement and the reference documents supporting the various sustainability claims can be found at the Cement Association of Canada website (www.cement.ca).

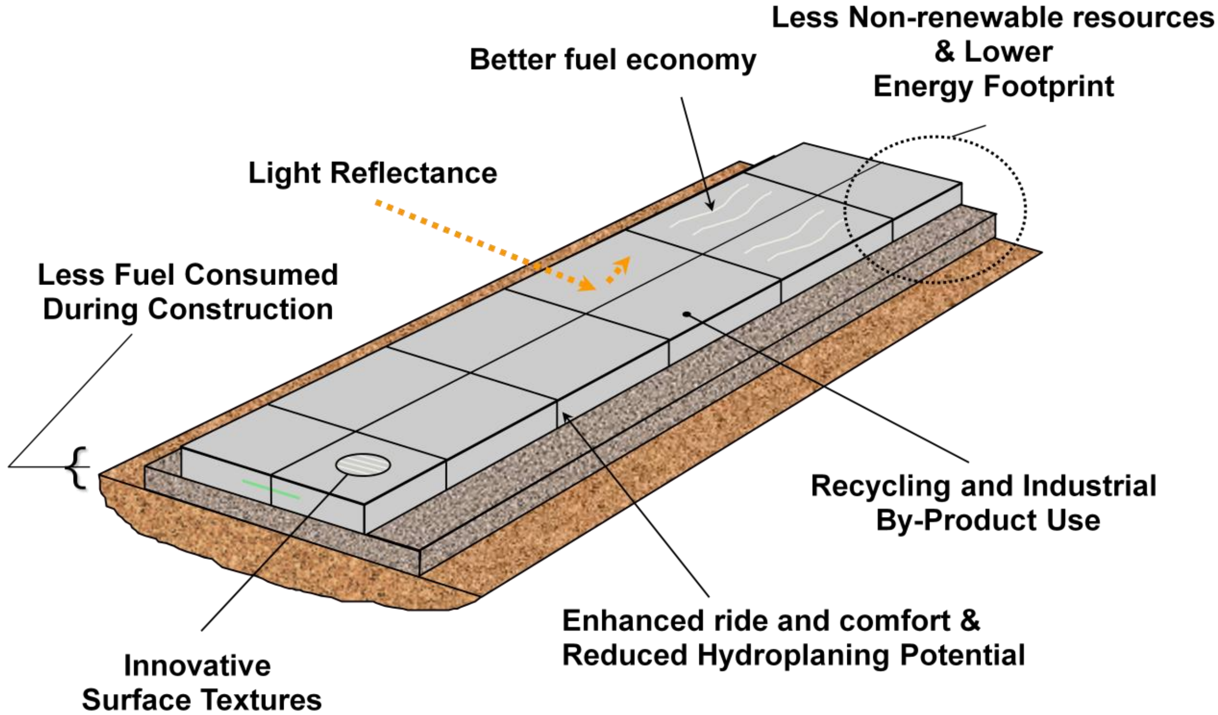

Figure 5: Concrete Pavements Many Sustainability Benefits Beyond Longevity
Source: Helping Build A Sustainable Future by Constructing Roadways with Portland Cement Concrete Pavement [Smith 2006]

6.1 Economic Benefits

There are many economic benefits of using concrete pavement. Listed below are several of these benefits:

a. **Minimal pre-overlay work required** - existing pavement is used as a base for the new concrete pavement and thus does not need to be removed. Little or no repairs are usually required to the existing pavement prior to placing the concrete overlay.

b. **Stable concrete prices as compared to asphalt –** Concrete pavement costs do not fluctuate like asphalt as they are not as closely linked to fluctuating oil prices.

c. **Variety of overlay thickness applicable** – the thickness of the overlay can be varied depending on the amount of traffic it is estimated to carry and the desire pavement life.

d. **Single pass is used for placing the concrete pavement** – Concrete pavement slipform pavers are capable of paving two lanes at the same time.

e. **"Fast Track Construction"** – fast track techniques enable new concrete pavements to be opened to traffic within a day of placement

f. **Less maintenance and rehabilitation interventions** – Due to concrete pavement's longevity less maintenance and rehabilitation activities are required over its lifetime.

g. **Stands up to seasonal stresses** – Concrete pavement's rigid structure does not rely on the strength of the underlying granular base material like an asphalt pavement does so it is not affected by weakening of the granular material during the spring thaw period.

h. **Reduces lighting costs due to reflective surface** – Concrete pavement reflects light in a diffuse manner compared to asphalt's slightly specular manner. This results in the asphalt requiring more lights per unit length of pavement than its concrete pavement alternative.

6.2 Environmentally and Socially Friendly

Concrete has many environmental and social benefits. Listed below are some of these benefits:

a) **Reduced fuel consumption and related emissions for heavy trucks** – Based on the findings of the NRC fuel studies one can confidently say there is statistically significant fuel savings from operating on PCCP compared to ACP ranging from 0.8 to 6.9 %. [Taylor 02] [Taylor 06] Table 1 identifies the yearly potential fuel saving and associated $, CO_2 Equivalent, NOx, SO_2 savings over a year period if a 100 km section of a typical major urban arterial highway was PCCP. The savings are based on the following assumptions: heavy truck fuel efficiency of 43 litres / 100 km; diesel fuel cost of $0.8964 / litres; and highway section carrying 20,000 vehicles per day at 15% heavy truck traffic.

Table 1
Yearly Potential Savings in $, CO_2 Equivalent, NO_X, SO_2

For Typical Major Urban Arterial Highway

% Fuel Savings	Fuel Saved (litres)	Fuel Savings ($)	CO_2 Eq (tonnes)	NO_X (kg)	SO_2 (kg)
0.8 min.	376,680	$337,656	1039	11,758	1,486
3.85 avg.	1,812,772	$1,624,969	5000	56,585	7,152
6.9 max.	3,248,865	$2,912,282	8960	101,413	12,818

Note: CO_2 Equivalent calculations include carbon dioxide, methane and nitrous oxide.
CO_2 = carbon dioxide, NO_X = nitrogen oxides, SO_2 = sulphur dioxide

In conclusion there are significant CO_2, NO_X and SO_2 savings when operating tractor-trailers on PCCP versus ACP. This means less pollutants being emitted into the environment, reduced fuel consumption, decreased trucking firms' operating costs, and possibly reduction in cost of goods to consumers.

b) **Recycling of industrial byproducts in concrete mix** – Concrete is a mixture of fine and coarse aggregate, cement, water and admixtures. However, it is possible to replace a portion of cement with a variety of industry by-products often referred to as supplementary cementing materials or SCMs. These materials, if used in the proper proportions, will enhance the properties of the concrete mix, as well as, stabilize any by-product material in the concrete structure rather than dumping them at local landfill sites. The three most commonly used SCMs are fly ash (by-product of coal burning), blast furnace slag (by-product of steel manufacturing) and silica fume (by-product of manufacture of silicon or ferrosilicon alloy). Ternary blends (i.e. cement combined with two of the three most common SCMs) are also being used in Canada. In fact, a few of the Portland cement concrete pavement (PCCP) installations in Québec have used ternary cements. Using SCMs can enhance the concrete properties including improved durability, permeability and strength. Fly ash, blast furnace slag and silica fume can also help control alkali - silica reactivity also known as ASR (a chemical reaction that occurs when free alkalis in the concrete combine with certain siliceous aggregates to form an alkali-silica gel. As the gel forms, it absorbs water and expands, which cracks the surrounding concrete) [Kosmatka 2002]. Fly ash and blast furnace slag also improve workability of the concrete mixtures.

Another important benefit of utilizing SCMs in concrete pavement is the reduction of CO_2 emissions and energy use associated with the concrete structure. The SCMs replace a portion of the cement in the concrete mixture and thereby decreases the total amount of CO_2 and its embodied energy total. The amount of CO_2 and energy reduction is directly related to the percentage of the SCM used in the mix design.

c) Reduced energy consumed to build and maintain - In 2006 the Athena Institute performed an update to an earlier study looking at the Life Cycle Assessment (LCA) of several concrete and asphalt pavement structures to evaluate the energy use of the various pavement structures over a 50 year evaluation period. Table 2 below shows in each case the concrete pavement options had a lower energy footprint (embodied primary energy) than its equivalent asphalt pavement option. Even if the feedstock energy (liquid bitumen) is removed from the analysis the concrete pavement options still have a better energy footprint. It should be noted, however, ISO 14040 section 4.2.3.3.2 states, "Energy inputs and outputs shall be treated as any other input or output to an LCA. The various types of energy inputs and outputs shall include inputs and outputs relevant for the production and delivery of fuels, feedstock energy and process energy used within the system being modeled." Therefore, gross combustion heat value of liquid bitumen must be included in any LCA. Details on the study can be found in the reference entitled, "A Life Cycle Perspective on Concrete and Asphalt Roadways: embodied Primary Energy and Global Warming Potential". [Athena 2006]

Table 2
Additional Embodied Primary Energy Used by
Asphalt Pavement Design Alternatives

Highway Classification	Additional Embodied Primary Energy Used by Asphalt Pavement Design Alternatives	
	Including feedstock energy	Excluding feedstock energy
Canadian Arterial Highway		
- CBR 3	3.9 times more	67 % more
- CBR 8	4.1 times more	68 % more
Canadian High Volume Hwy		
- CBR 3	3.0 times more	66 % more
- CBR 8	3.0 times more	67 % more
Quebec Urban Freeway	5.3 times more	81% more
Ontario Highway 401 Urban Freeway	2.3 times more	31 % more

Source: The Athena Institute [Athena 2006]

d) **Reusable material** – Concrete pavement can be reused by performing concrete pavement restoration (CPR) techniques on the damaged areas. Repair techniques such as full depth / partial depth repairs, load transfer restoration, slab stitching, slab jacking and diamond grinding can be used to restore the pavement to an almost new condition. All these repair activities have low energy use and CO_2 footprints while restoring an older concrete pavement to an almost new condition. The final product is a smooth concrete pavement that will provide a long lasting surface with all the sustainable benefits of a new concrete pavement.

Concrete pavement can also be placed over existing asphalt pavements to create a new composite pavement structure. The existing asphalt pavement structure becomes a strong base for the new concrete overlay. In fact, the known performance of the asphalt pavement will minimize the potential for pumping, faulting and loss of support in the new concrete pavement. No repairs are required to the existing ACP unless there are large areas of soft spots or the pavement ruts are over 50 mm. The key point is that the asphalt pavement is reused, therefore, minimizing the amount of reconstruction required and the associated emissions with it.

e) **Recyclable material –** Concrete pavements are 100 % recyclable and can be removed economically when necessary. They can be reused as high quality, drainable base material for new pavement or possibly as recycled aggregate in the new concrete pavement.

f) **Utilizes less granular material** – Since the concrete pavement is being placed directly on the deteriorated asphalt pavement there is no additional granular material required to rebuild the roadway unlike potential asphalt reconstruction options.

g) **Safety enhancements** – Concrete pavement surfaces minimize pothole potential, decrease potential for hydroplaning, provide good skid resistance and improve night time visibility.

7.0 Canadian Concrete Pavement Overlay Projects

As noted in the introduction, there are many examples of concrete overlays in Canada ranging from overlays at truck weighing facilities, bus stops, intersections and city streets. This section of the report gives four examples of bonded and unbonded overlays throughout Canada.

7.1 Mississauga, Ontario Bonded Concrete Overlay

Bonded Concrete Overlays were first used in Canada in 1995 to rehabilitate a northwest quadrant of the intersection at Britannia and Dixie Roads in Mississauga which was subject to extensive rutting due to heavy truck traffic. The damaged asphalt was milled out and replaced by an average of 140 mm of thin bonded concrete overlay. The thickness of the remaining asphalt after milling varied from 51 to 235 mm. Joints were saw cut in 1.6 m square panels. As shown in Figure 6 below this intersection carry's a large number of trucks (1700 heavy trucks/day in 1995). A 2010 visual inspection revealed that even after minimal repairs over its lifetime the 14 ½ year old concrete overlay was still in very good condition with minimal cracks and spalling.

Figure 6 - Mississauga Bonded Concrete Overlay Condition after 14 1/ 2 Years of Service

7.2 Lethbridge, Alberta Bonded Concrete Overlay

Another example of the proven performance of bonded concrete overlays is the resurfacing of two turning lanes at a highway intersection in Lethbridge, Alberta in 2004. This intersection was also suffering from severe rutting due to heavy truck traffic and conventional asphalt repairs were lasting for only a year or two. Alberta Transportation sought a durable, long-term solution to the rutting issues and chose a Bonded Concrete Overlay solution. The concrete was placed over the original asphalt milled down to an average depth of 125 mm in the outside heavy truck traffic lane and 100 mm on the inside lane. Joints were saw cut into the concrete pavement at 1.5 m intervals. The minimum compressive strength was 20 MPA at 3-days and 30 MPA at 28 days. The concrete overlay repair took only two days to complete. Synthetic structural fibers were utilized but no dowels of tie bars were used. After five plus years of service the overlay is performing very well with no maintenance required to date.

7.3 Toronto, Ontario Unbonded Concrete Overlay

An unbounded concrete overlay was constructed in the summer of 2003 at a heavily-trafficked "T" intersection on Bloor Street and Aukland Road in the City of Toronto. Bloor Street is a four lane major East-West arterial road carrying about 30,000 vehicles per day in 2003 with extremely heavy peak hour traffic. It is also a major bus route to the nearby Kipling Subway station through Aukland Road. The original pavement structure along Bloor Street was a composite pavement and Aukland Road was a full depth asphalt pavement. Figure 7 below illustrates the original pavement structure and the new pavement structure. The original pavements were severely rutted/raveled with reflective and alligator cracks. On Bloor Street, the original asphalt concrete surface was completely removed by milling to the underlying concrete base. The concrete base was tack coated before placing a 25 mm asphalt debonding layer followed by 150 mm of 32 MPa concrete. Contraction joints were cut in a grid pattern at a maximum spacing of 1.5 m and to ¼ of pavement depth. Dowel bars were only used in the curb lane areas were the buses stop prior to turning. Table 3 gives details on the concrete pavement mix design. A 2010 winter visual inspection showed that the entire pavement structure is still in excellent condition after 6 1/2 years service with only some cracks at the catch basin areas. See Figure 8 for picture of the Bloor Street unbonded concrete overlay.

Figure 7: Pavement Structures Bloor Street West Section, Toronto, Ontario

Table 3

Concrete Mix Design

Min. Compressive Strength	32 MPa
Accelerated Strength	20 MPa in 72 hrs.
CSA Exposure Class	C2
Max. Water/Cement Ratio	0.45
Min. Cement Content	335 kg/m^3
Cement Type	10/GU
Nominal Size Aggregate	19 mm
Stone Type	Limestone
Air Content	5-8 %
Max. Slump	80 mm

Figure 8: Bloor Street, Toronto Unbonded Concrete Overlay Condition after 6 ½ Years Service

7.4 Edmonton, Alberta Unbonded Concrete Overlay

The Yellowhead Trail, a six-lane divided highway with access to major arterials by signalized intersections and interchanges in Edmonton Alberta has a section of Unbonded Concrete Overlay. As a major truck route running east west through the northern half of the city of Edmonton, it carries approximately 8000 heavy trucks per day. Two particular sections of the roadway between 124 and 127 Streets, west of the Municipal airport, required asphalt overlay every two years due to severe rutting. To overcome this continuous asphalt rutting problem, two Portland Cement Concrete Pavement (PCCP) inlays were installed in 1994:

- 200 metre, 3 – lane section west of 127 Street in the eastbound lanes, and
- 300 metre, 3 – lane section east of 127 Street in the westbound lanes.

Treatment lengths were based on the amount of rutting which occurred in each direction. The existing asphalt pavement was 300 mm thick placed on a 150 mm layer of soil cement. A 225 mm unbounded concrete overlay was placed at the damaged areas by milling out the existing asphalt and leaving 75mm as support for the new PCCP. [Soleymani 2005] A visual inspection showed that after 15 plus years of service the concrete inlays are in very good condition and have had only minor maintenance - some joint sealant replacement.

8.0 Conclusion

Concrete overlays provide government agencies a sustainable and cost effective option to help deal with their ever deteriorating roadway infrastructure. Three bonded and unbonded concrete overlay solutions are available to designers to deal with various maintenance and rehabilitation issues on roadway networks. Utilizing concrete overlays also brings with it the many sustainable benefits of using concrete pavement such as truck fuel savings, decreased energy use, better night time visibility, reusable/recyclable, decreased granular requirements, decreased lighting costs and use of industrial by products in pavement.

Based on the many benefits concrete overlays provide they should be considered in government agencies maintenance and rehabilitation tool boxes as a valuable repair and reconstruction option.

9.0 References

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